

D 010 193

1-30-67 24

(REV)

FACTORS AFFECTING PITCH DISCRIMINATION.

BERGAN, JOHN R.

HVL27509 UNIVERSITY OF KANSAS, LAWRENCE

CRP-S-154

BR-5-8468

- -66 DEC-5-10-185

EDRS PRICE MF-\$0.09 HC-\$1.64 41P.

*AUDITION (HEARING), *VISUAL PERCEPTION, FEEDBACK,
*AUDITORY PERCEPTION, EXPERIMENTAL PROGRAMS,
*AUDITORY DISCRIMINATION, LAWRENCE, KANSAS

EFFECTS OF TONAL MEMORY OF TWO KINDS OF FACTORS WERE STUDIED. THE FACTORS WERE (1) THE CHARACTERISTICS OF STIMULI PRESENTED TO THE SUBJECT IN A PITCH IDENTIFICATION TASK, AND (2) THOSE EFFECTING THE RESPONSE THAT THE SUBJECT MAKES IN SUCH A TASK. FIVE HYPOTHESES WERE ADVANCED FOR STUDY. THE UNDERLYING ASSUMPTION WAS THAT THERE ARE IMPORTANT DIFFERENCES BETWEEN THE ACQUISITION OF LONG-TERM PITCH MEMORY AND THE ACQUISITION OF SHORT-TERM PITCH MEMORY. THREE EXPERIMENTS WERE CONDUCTED. THE FIRST EXPERIMENT WAS CONCERNED WITH TONAL MEMORY AND IDENTIFYING RESPONSE, THE SECOND EXPERIMENT WITH ACTIVITY LEVEL AND TONAL MEMORY, AND THE THIRD EXPERIMENT WITH THE EFFECTS OF VARIATIONS IN INTENSITY LEVEL AND FEEDBACK ON PITCH IDENTIFICATION. RESULTS INDICATED THAT (1) LEARNING DID NOT OCCUR WHEN THE DELAY BETWEEN THE STANDARD AND VARIABLE TONE WAS 10 SECONDS, (2) THE 50-DECIBEL STANDARD PITCH WAS SUPERIOR TO THE 50-DECIBEL VARIABLE PITCH, (3) AUDITORY FEEDBACK IS SUPERIOR TO VISUAL FEEDBACK AND DELAYED FEEDBACK IN FACILITATING PITCH IDENTIFICATION, AND (4) IT IS ADVANTAGEOUS TO PROVIDE IMMEDIATE AUDITORY FEEDBACK TO STUDENTS IDENTIFYING PITCHES. (HB)

ED010193

(5-8468)

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education

This document has been reproduced exactly as received from the person or organization originating it. Points of view or opinions stated do not necessarily represent official Office of Education position or policy.

FACTORS AFFECTING PITCH DISCRIMINATION

Cooperative Research Project No. ^{S-154} 154

John R. Bergan
University of Kansas
Lawrence, Kansas
1966

The research reported herein was supported by the Cooperative Research Program of the Office of Education, U. S. Department of Health, Education, and Welfare.

Table of Contents

	Page
TABLES	3
PROBLEM	4
HYPOTHESES	4
RELATED RESEARCH	6
PROCEDURE AND DATA ANALYSIS	11
Experiment I. Tonal Memory and Identifying Response	11
Experiment II. Activity Level and Tonal Memory	22
Experiment III. Effects of Variations in Intensity Level and Feedback on Pitch Identification	23
CONCLUSIONS AND IMPLICATIONS	35
REFERENCES	38
Table 5. δ Ratios Between Conditions Involving Variations in Intensity of the Standard Tone	30
Table 7. δ Ratios Between Conditions Involving Variations in Intensity of the Variable Tone	31
Table 8. δ Ratios Between Conditions Involving Variations in Feedback	32

List of Tables

	Page
Table 1 Means and Variances for Pretest Data	16
Table 2 Means and Variances of Mean Log Error Scores for Post- test Data Expressed in Logs and Semitones	17
Table 3 Rank Differences and Associated Significance Levels Used in Computing Wilcoxon's Signed Rank Test for Posttest Data	18
Table 4 Trend Analysis of Condition 4 Subjects Across 8 Blocks Consisting of 2 Trials Each	19
Table 5 Means and Variances of Subjects' Log Deviations in Training and Test Performances for the 9 Experimental Conditions Expressed in Logs and Semitones	29
Table 6 F Ratios Between Conditions Involving Variations in Intensity of the Standard Tone	30
Table 7 F Ratios Between Conditions Involving Variations in Intensity of the Variable Tone	31
Table 8 F Ratios Between Conditions Involving Variations in Feedback	32

Problem

This project is an investigation of the effects on tonal memory of two kinds of factors: those changing the characteristics of stimuli presented to the subject in a pitch identification task, and those affecting the response that the subject makes in such a task. The task in all cases was to match the pitch of a 932 cps tone by adjusting the frequency of an oscillator emitting a variable tone when an interval of silence occurred between the two tones. In the study of changes in stimulus characteristics, focus was on the influence of alterations in intensity. Three factors affecting responses were studied: the duration of silence between the standard and variable tone, feedback concerning past performance, and sensory activity level of the subject (i.e., the amount of sensory stimulation which the subject experienced prior to and during pitch judgment performance).

Hypotheses

The following general hypotheses were advanced:

1. Subjects allowed to match a variable tone to a standard immediately following the cessation of the standard will perform better on a test of tonal memory than subjects who are not permitted to respond to the standard immediately following its cessation.
2. High activity level of the organism will result in less accuracy in pitch judgment than low activity level.
3. Both visual and auditory feedback will facilitate pitch judgment; auditory feedback, however, will be more effective than visual feedback.
4. Training with a standard tone of moderate intensity will facilitate judgment more than training with a standard of either high or low intensity.

5. Increasing the intensity of the variable tone will result in a decrease in accuracy in pitch judgment.

Three experiments, which will be described in detail below, were designed to test these hypotheses.

Underlying all of the above hypotheses is the assumption that there are important differences between the acquisition of long term memory for pitch (i.e., memory involving a delay between the standard and variable tone of more than 4 seconds) and the acquisition of short term pitch memory. A model describing separate long term and short term memory systems provides a way to represent these differences. The short term system in this model is assumed to come into operation as a direct result of sensory experiences and thought to be capable of storing incoming sensory information for a limited time only. Decay of memory traces in this system is assumed to take place rapidly so that the amount of information available with respect to a given stimulus is reduced drastically within seconds after its termination. The long term system is thought to differ from the short term system in two ways: First, memory traces in the long term system are assumed to occur as a result of responses identifying the characteristics of stimuli to be remembered. Second, information stored in the long term system is available for extended time periods.

In accordance with the above conception of memory systems, it was assumed that tonal memory could be facilitated in two ways: first, by influencing the information processed by the short term system, second, by affecting access to the long term system either by altering the opportunity to the organism to make an identifying response with respect to the stimulus to be remembered or by changing the degree of receptivity of the long term system to new information.

The first and third hypotheses advanced above, those involving the silent interval between the standard and variable tone and the influence of visual and auditory feedback, are concerned with effects on the subject's opportunity for making an identifying response. The hypothesis involving reduced activity level deals with alterations in the receptivity of the long term system. The last two hypotheses, those concerned with variations in stimulus intensity, deal with effects on information processing in the short term system. As mentioned above, the short term system is assumed to be activated directly by sensory experience. The general question underlying hypotheses four and five is: Do changes in sensory experience associated with changes in intensity level affect the ability of the short term system to process information concerning pitch?

Related Research

There are a number of studies in the existing literature dealing with the distinction between short term and long term memory. Investigations in this area have in the vast majority of instances dealt with verbal learning. This is unfortunate so far as the present project is concerned since there are important differences between verbal learning and the acquisition of pitch identification skill. Nevertheless, literature in verbal learning does shed light on the process of learning to identify pitches. The most important finding in this connection is that there is a change in verbal memory associated with lengthening the time between stimulus presentation and response. In early verbal learning studies it was found that increasing the time between the presentation of a stimulus and the response to that stimulus facilitated performance (Bergstrom, 1919; Guthrie, 1933). This finding was reconfirmed much later by McReynolds and

Acker (1959). It has been assumed by a number of investigators that the reason for the observed facilitation is that subjects are given an opportunity to covertly rehearse relevant responses during the delay interval. The facilitation effect might then be assumed to be simply the result of increased opportunity for practice. In apparent accordance with this view is the well known finding that when activities are interposed between stimulus presentation and response memory is impaired (Peterson and Peterson, 1959; Pillsbury and Sylvester, 1940). In certain instances this detrimental effect may be the result of interference associated with the interposed activity. However, it is also possible that a lack of rehearsal impairs performance. The latter notion has important implications for the theoretical explanation of memory in that it suggests that sensory experience alone may not be responsible for the occurrence of memory. Responses may play an important role in the formation of memories.

Broadbent (1957) did a study in which he examined the role of responses in information storage. In this study subjects heard six digits in one ear and two in the other and were required to report all eight digits, first the six and then the two. When the two came near the end of the series of six, subjects performed much better than when the two were presented near the beginning or middle of the series. Broadbent argues that the inferiority of performance in the latter two situations is a result of the fact that the delay between stimulus presentation and response is longer in those cases than when the two digits are presented near the end of the series of six. There was no opportunity for subjects to rehearse in this experiment since during the delay between the presentation of the two digits and the response to these digits they were busy reciting the six digits.

Broadbent (1957) hypothesizes a dual memory system similar to the one suggested in this project. He labels the short term system the S system and the long term system the P system. According to Broadbent information stays in the S system for a limited time only but after passing through the P system can be restored to the S system by rehearsal.

Broadbent's views represent a marked departure from gestalt conceptions of memory which have dominated thinking in American psychology for nearly a half century. Gestalt theorists have not recognized the role of rehearsal in memory and do not postulate two memory systems. However, Broadbent's position is by no means totally opposed to the gestalt view. The function of rehearsal, according to Broadbent, is to restore traces based on sensation. Thus, memory in both the Broadbent and gestalt conceptions is composed of traces formed by sensory experience.

Undoubtedly, one of the reasons why the role of response in memory formation has not been clarified in the past is that rehearsal can take place covertly. It is difficult to determine whether memory is formed from sensory experience or identifying responses or both when relevant responses must go unobserved. There are differences between tonal memory and verbal memory which are of importance with respect to this situation. Studies involving verbal memory typically require a series of responses, such as, for example, repeating a set of digits. The individual responses in the series are invariably already stored in memory before the experiment ever begins. The subject is not required to remember the stimuli presented, but rather the order of presentation or some other relational aspect of the stimuli. The fact that relevant responses are already stored in memory makes covert rehearsal possible.

In a pitch identification task, it may in many instances be impossible for the subject to rehearse covertly. The subject may not have a set of responses already built in before the experiment begins, or if he does have such a set of responses, they may be no more than rough approximations to the stimuli which they represent. Indeed, the problem in pitch identification is to acquire a response or set of responses which represents an external stimulus. Studies in pitch identification, then, are particularly well suited to the problem of determining the basis for memory storage. The problems associated with covert rehearsal should not be of the same magnitude in studies in pitch judgment as they are in investigations of verbal learning. It should not be necessary to interpose activities between stimulus and response to demonstrate a decrease in memory as the time interval between the standard tone and response to that tone is increased. A study by Harris (1952) is of interest in this regard. Harris employed two procedures, both involving the method of constant stimulus differences. In the first, the standard tone remained constant for all comparisons. In the second, which he called the roving standard procedure, the standard tone was varied in five cycle steps through a range extending from 950 cps to 1000 cps. With the fixed standard procedure there was no difference in D.L.s obtained from .3 to 3.5 seconds. The D.L. declined less than one cycle per second over a time period extending from .1 to 15 seconds. However, with the roving standard a decline of 1 cps in the D.L. was noted after only 4 seconds. The facilitation effect associated with delay between stimulus and response in verbal learning studies is not demonstrated by Harris' data.

According to the view taken in this project, the importance of variation in the time delay between a stimulus and a response is related to the

changes which such variation creates in opportunity for making an identifying response. As the delay increases, the opportunity to make an identifying response decreases. It might be assumed that if there were some way to make identifying responses possible without reducing the delay between stimulus presentation and response, delay would not seriously impair performance. The concept of feedback is important in this connection.

It has long been assumed that insofar as an individual is provided information about the accuracy of past performance, he is afforded the opportunity to make future performance more accurate (Stevens, 1951). Increase in accuracy associated with feedback would suggest that memory for pitch is determined by the occurrence of accurate responses in addition to the imitation of sensory experience. Little information is available on the effectiveness of feedback in pitch identification learning. In a study by Pollack and Johnson (1959), feedback was found to enhance pitch judgment. However, Campbell and Small (1963) found that feedback not only had no beneficial effect on performance, but actually seemed to impair performance. This finding will be considered in detail in the discussion of Experiment III.

To this point, attention has been focused on studies concerned with alterations in the opportunity for making an identifying response. Studies related to the effects of intensity on processing in the short term system and related to the effects of reduced activity level on access to the long term system will now be considered briefly. There is very little information in existing literature which deals with either the effects of intensity on pitch judgment or with the effects of reduced activity level on pitch identification. A study by Shower and Biddulph (1931) is of interest with regard to the effect of intensity on pitch discrimination.

These investigators found that discrimination improves with increases in intensity up to 20 decibels and then levels off. This indicates that intensity does affect performance. Two important differences exist, however, between the Shower and Biddulph study and the type of investigation conducted in this project. The first of these is that the Shower and Biddulph study is concerned with auditory acuity rather than auditory memory. The second difference, related to the first, is that these investigators do not distinguish between learning and performance.

The hypothesized relationship between pitch judgment and activity level was made on the basis of the assumption that reduced activity level would facilitate access to the long term system. There are numerous studies which suggest that under reduced sensory stimulation, visual and auditory experiences may become extremely vivid and often assume hallucinatory character (Solomon, et al., 1961). There is no evidence, however, concerning whether these vivid experiences are based only on responses built in before reduced stimulation or whether reduced stimulation makes the long term system easily accessible.

Procedure and Data Analysis

Experiment I

Tonal Memory and Identifying Response

This study is based on the assumption that tonal memory, defined operationally as the ability to match the pitch of a variable tone to that of a standard tone when 10 seconds of silence intervene between the two tones, is acquired at least in part as the result of the influence of identifying responses.

The central hypothesis is that subjects trained under an identifying response condition allowing them to match the pitch of a variable tone to

that of a standard tone immediately after the cessation of the standard tone will make better scores on a posttest measuring tonal memory than subjects trained under any of the following three conditions: 5 second presentation of the standard tone followed by 45 seconds of silence; 5 second presentation of the standard tone followed immediately by the variable tone without adjustment of that tone by the subject; 5 second presentation of the standard tone followed by 10 seconds of silence, then presentation of the variable tone and adjustment of that tone by the subject.

Memory for pitch is considered in this study as an intervening variable defined on the one hand by an incoming stimulus, the tone to be remembered, and on the other hand by an identifying response to that stimulus occurring after an interval of time. The word "identifying" suggests that in order for a response to serve as an operational definition of memory it must, at least to some extent, point out the distinguishing characteristics of the stimulus to be remembered.

In the past, in connection with this descriptive paradigm of tonal memory, or for that matter memory in general, it has been assumed that an incoming stimulus may have the capacity to leave a lasting imprint in the nervous system. The gestalt concept, stimulus trace, is a good example of this view of memory. According to the gestalt view, the incoming stimulus is assumed to be responsible for creating those modifications within the organism which underlie memory. Not only does the incoming stimulus provide a definition of memory by describing that which is to be remembered, but also it produces those changes within the organism upon which memory is based. The identifying response indicates the presence of memory. That is, it serves as a signal implying that memory has occurred.

It is not, however, assumed to produce those modifications which result in the internal representation of the stimulus.

The central hypothesis underlying this experiment is that effects of the identifying response are stored in memory. It cannot be overlooked that the influence of a stimulus tone does persist after it is no longer present in a given situation. This, indeed, is a well documented fact (Harris, 1952; Konig, 1957). However, it is also a fact that such influence decreases rapidly with time (Harris, 1952; Konig, 1957). The concern of the present study is with influences which persist despite a lapse of time.

In order for an identifying response to take place it must occur when there is a stimulus present to identify. In the first condition described, the response is made in close temporal conjunction with the standard stimulus. In this condition an identifying response is possible.

The second condition mentioned provides ample opportunity for the standard stimulus to exert its influence by producing stimulus traces. However, there is little opportunity for making an identifying response since the subject is not permitted to adjust the oscillator. If identifying responses do affect tonal memory, subjects trained under the first condition should perform in a superior fashion to those trained under the second condition.

The third condition permits the subject to hear both the standard and variable tone, but does not allow her to make an identifying response. It is assumed that learning will not be increased by merely hearing the standard followed by the 500 or 1700 cps variable. In order for learning to be enhanced an identifying response must occur.

The fourth condition is identical to the test condition. It allows the subject to respond. However, since the response occurs after 10 seconds of silence, the influence of the standard tone has already decreased substantially. It was assumed that the hypothesized superiority of performance in the first condition would not be the result of its similarity to the test condition and that in consequence performance in the first condition would be superior to that in the fourth condition.

Method

Forty-eight female subjects from the University of Kansas educational psychology pool were used for this investigation.

The sound system used for the experiment consisted of two Houston Instrument Type J1 oscillators connected to an external switch box capable of channeling the sound from either oscillator into a set of Permoflux PDT8 earphones inside a sound-proof room. The frequency response of these earphones was $\pm .5$ decibels from 500 to 1700 cps. A frequency counter and a voltmeter were connected to the two oscillators enabling measurement of the frequency and intensity of the tones emitted. The duration and sequence of tone presentation were automatically controlled by interval timers. The oscillator that was adjusted by the subject was modified by covering the dial to prevent visual cues in repeated adjustments and was restricted in range to adjustments between 500 cps and 1700 cps.

Subjects were given a pretest involving judgments of a tape recorded piano tone (A 440 cps). First the standard tone was presented. Then following a 15 second period of silence a series of 15 variable tones were presented at 3 second intervals. The subjects were instructed to indicate

for each tone whether or not it was identical to the standard. There were 18 trials. A score for each subject was determined by counting the number of variable tones incorrectly judged.

On the basis of this pretest, subjects were matched and assigned at random to one of four training conditions. Subjects trained under each of these conditions were then given a test assessing tonal memory. In all conditions total time per trial was 50 seconds. The subjects' responses were recorded from the frequency counter. Forty training trials and 25 test trials were given. For all trials the intensity of the tones presented was approximately 40 decibels.

Training Condition One. A standard tone of 932 cps was presented for 5 seconds followed immediately by a 25 second presentation of a variable tone (500 and 1700 cps alternately). The subject attempted to match the variable tone to the standard by adjusting the oscillator dial. Following the 25 second presentation of the variable tone there was a 20 second period of silence. In the silent interval between trials, the subject set the oscillator dial alternately at the 500 cps or 1700 cps position.

Training Condition Two. This condition consisted of the presentation of the standard tone for 5 seconds followed by 45 seconds of silence.

Training Condition Three. The standard tone was presented for 5 seconds followed immediately by a 25 second presentation of the variable tone. No adjustment was made. A 20 second period of silence preceded the next trial.

Training Condition Four. The standard tone was presented for 5 seconds followed by 10 seconds of silence. At the end of 10 seconds of silence the variable tone was presented for 25 seconds. The subject's

task, as in condition one, was to match the pitch of the variable tone to that of the standard. A 10 second period of silence then preceded the next trial.

The training sessions were followed by a test condition identical to condition four. A subject's score on the posttest was the mean deviation of the logarithms of her frequency judgments from 932 cps. Logarithms were used because frequency judgments rendered in cps do not provide a pitch scale with equal intervals whereas logarithms do.

Results and Discussion

Pretest means and variances for subjects assigned to each training condition are given in Table 1. Bartlett's test for homogeneity of variance (Winer, 1962) revealed no significant differences in the variances. An F test (Winer, 1962) revealed no significant differences in pretest means.

Table 1

Means and Variances for Pretest Data

	Condition 1	Condition 2	Condition 3	Condition 4
Means	24.1	23.9	22.9	24.3
Variances	341.74	323.61	336.41	321.59

Means and variances based on posttest scores are reported in log deviations in Table 2. For convenience of interpretation these scores are also transformed into semitones. Because of heterogeneity of variance Wilcoxon's Match-Pairs Signed Ranks Test was used in making comparisons of performances of the training groups in the test condition (Wilcoxon and Wilcox, 1964). The results of the Wilcoxon tests computed for

each of the six possible pairings of the four conditions studied in the experiment are given in Table 3. As predicted, significant differences

Table 2

Means and Variances of Mean Log Error Scores
for Posttest Data Expressed in Logs and Semitones

	Condition 1		Condition 2		Condition 3		Condition 4	
	Logs	Semitones	Logs	Semitones	Logs	Semitones	Logs	Semitones
Means	.0185	.75	.0523	2.10	.0592	2.37	.0549	2.20
Variances	.0002	.00	.0023	.10	.0055	.23	.0022	.10

between ranks were obtained for the three comparisons involving in turn the pairing of condition one, the immediate adjustment condition, with each of the other three conditions. The performance in the test condition of subjects trained under condition one was superior to the performance of subjects trained by all other methods. Furthermore, there were no significant differences between test performance of subjects involved in any comparisons between training conditions which did not include condition one.

It could be argued that the reason that subjects in condition one performed in superior fashion to those trained under other conditions is that condition one subjects simply had more exposure to the standard tone than other subjects. Insofar as subjects during training under condition one were able to adjust the variable tone to match the standard, they were exposed to the standard not for 5 seconds but for nearly 30 seconds during each trial. That is, not only did they hear the standard tone during the 5 second presentation at the beginning of each trial, but also after each adjustment they heard tones approximating the standard for nearly 25 seconds.

Table 3

Rank Differences and Associated Significance Levels Used in Computing
Wilcoxon's Signed Rank Test for Posttest Data

	Conditions 1-2	Conditions 1-3	Conditions 1-4	Conditions 2-3	Conditions 2-4	Conditions 3-4
Block* 1	+ 1	- 2.5	- 1	+ 2	+ 1	+ 1
Block 2	-12	- 2.5	- 8	- 9	-10	- 8
Block 3	+ 2	-11	- 5	+12	- 2	+12
Block 4	- 8	+ 4	- 6	- 4	- 3	- 5
Block 5	-11	- 1	- 9	- 8	- 7	-10
Block 6	- 3	- 5	- 2	- 1	- 4	+ 2
Block 7	- 4	+ 7	+ 3	- 3	- 5	- 3
Block 8	-10	- 9	- 4	-10	-11	- 6
Block 9	+ 6	- 8	-10	+ 5	+12	- 9
Block 10	- 7	+ 6	- 7	- 6	- 6	- 7
Block 11	- 9	-12	-12	+11	+ 8	+11
Block 12	<u>- 5</u>	<u>-10</u>	<u>-11</u>	<u>+ 7</u>	<u>+ 9</u>	<u>+ 4</u>
	+ = 9 ^b	+ = 17 ^a	+ = 8 ^b	+ = 37	+ = 30	+ = 30
	- = 69	- = 61	- = 70	- = 41	- = 48	- = 48

^a_p < .05

^b_p < .01

* A block is defined as four matched subjects each of which is assigned to one of the four training conditions.

What is being suggested here is that performance is a function of amount of exposure to the standard tone. However, the data do not support the assumption of a relationship between amount of exposure to the standard tone and performance. If amount of exposure were a factor in performance, then one would expect to see some improvement in performance with repeated exposure to the standard tone. The fact that such improvement did not occur may be shown by an examination of the performance of subjects trained under condition four. A trend analysis (Edwards, 1964), the results of which are presented in Table 4, revealed no change in accuracy of judgments of condition four subjects over 64 trials. Eight equally spaced blocks of two trials (i.e., trials 7-8, 15-16, 23-24, etc.) were used in this analysis. Mean log deviations were obtained for subjects at each two trial block. There were no significant differences between these means.

Table 4
Trend Analysis of Condition 4 Subjects Across 8
Blocks Consisting of 2 Trials Each

Source	SS	DF	MS	F
Trials	.002432735	7	.0003475	.734
Linear	.00123569	1	.00123	2.60093
Subjects	.437620492	11	.03978368	84.08*
T x S	.036425693	77	.00047306	
		95		

*p < .005

Results of the trend analysis do not support the assumption that performance is a function of amount of exposure to the standard tone. This might at first seem to contradict the well established fact that repetition can affect performance. However, it must be remembered that because of the 10 second delay repetition in condition four occurs with only minimal opportunity to make identifying responses.

An identifying response may be defined as behavior which describes the dimensions of a stimulus by imitating them. The identifying response used in this study was the adjustment of an oscillator to produce a tone matching the pitch of the standard tone. At least this was the overt identifying response. Is it not also possible that covert identifying responses could have been occurring? That is, would it not be possible for a subject to respond to the standard tone by forming an auditory image of it immediately after its cessation and in so doing establish memory for the standard tone? It is commonly accepted in studies of verbal learning that such covert responses occur and that they play an important role in influencing learning (McGeoch and Irion, 1952; Broadbent, 1957). There is, however, an important difference between studies of verbal learning and studies of pitch identification. In the former the identifying responses which indicate the memory of a given set of stimuli are characteristically part of the response repertory of the subject before he has entered the experiment. For example, a subject required to learn to recite a set of digits already knows how to say each of the digits before the experiment starts. The only thing he must learn is the order of presentation. It would be expected that such a subject could make covert identifying responses relevant to the digits as soon as they were presented.

The subject in a pitch identification study faces a different

situation. If he is to make a covert response, it may be one that he has never made before. Indeed, if it were possible for him to form an auditory image of the standard tone and this image were to persist for any length of time, one could say almost by definition that he remembered the standard. An auditory image is in essence an auditory memory. In this connection it is interesting to speculate about one finding in the study which, despite the fact that it is the invariable attendant of almost all studies, needs some explanation. Namely, individual differences in accuracy of pitch judgment within experimental conditions did occur. What accounts for them?

The adjustments of some subjects in each of the experimental conditions indicate that there are people who are able to identify the standard tone despite variations in training procedures. Beyond this it is a well known fact that some persons could have identified the standard tone simply on the basis of being told that it was B flat. On the other hand, some individuals in all conditions except condition one were unable to accurately approximate the standard tone. That is, their judgments characteristically varied as much as 300 to 400 cycles or more from the standard tone.

It may be that the reason for these individual differences is the fact that some subjects did not have in their repertory of responses covert responses for identifying tones while others did have such responses. Two studies by Bergan demonstrating a relationship between auditory imagery as measured by a questionnaire and skill in pitch identification provide support for this view. In the first of these (Bergan, 1965) a relationship between imagery and pitch identification was obtained for women but not for men. In the second (Bergan, in press) it was found that after employing a procedure for removing response bias from the imagery questionnaire, the

relationship obtained for both sexes.

The effectiveness of the overt identifying response, then, is assumed to be that it can for some subjects provide an identifying response where none was previously available. The superiority of condition one supports this assumption.

Another issue of importance in considering an identifying response explanation of tonal memory concerns the conditions necessary for an identifying response to take place. Condition one in the present study provides one set of circumstances which facilitate the occurrence of identifying responses. Might there not be others? A study by Pollack and Johnson (1959) bears on this point. These investigators, in addition to finding that two kinds of identifying responses, oscillator adjustment and whistling, were effective in improving pitch judgment also observed that verbal feedback was a facilitating factor. This latter might be described as a condition facilitating the occurrence of an identifying response. One way to make an identifying response possible is to allow the response to occur in close temporal conjunction with the stimulus. Another way is to provide the subject with useful information about his response. There may be many other ways.

Experiment II

Activity Level and Tonal Memory

The experiment on activity level will be described briefly. It was hypothesized that reduced activity level would facilitate accuracy in pitch judgment. Fifteen male subjects participated in the experiment. The apparatus was the same as that described in Experiment I. The subject's task, as in all experiments, was to adjust the pitch of the variable tone to match that of the standard tone. The S-V interval and interval between the end of

the adjustment period and the onset of a subsequent trial were both 5 seconds. Initially there were 12 trials. These trials were followed by a 15 minute period of reduced activity level during which the subject sat in a reclining chair and the sound-proof room was in total darkness, thus markedly reducing visual, auditory and kinesthetic input. At the end of the 15 minute period there were 12 additional trials carried out under the reduced activity level conditions.

An F test indicated that there was no significant difference between subjects' performances before and during reduced activity level. The hypothesized relationship between activity level and pitch judgment was not supported by the data.

It is possible that the period of reduced activity level was not long enough to be effective. However, various behavior alterations known to be associated with reduced activity level (for example, the occurrence of hallucinations) have been reported with periods of reduced stimulation as short as the one used in the present study (Solomon and Howes, 1961). Reduced stimulation may facilitate the transformation of information stored in the long term system into sensory experience. However, there is at present no support for the idea that reduced activity level increases access of newly acquired information to the long term system.

Experiment III

Effects of Variations in Intensity Level and Feedback on Pitch Identification

This study is an examination of the effects of variations in intensity level and type of feedback on learning in a pitch identification task. Effects on learning are distinguished from effects on performance as follows: When behavior in the experimental situation is influenced by a variable present in that situation (for example, feedback or intensity level),

that variable is affecting performance and may or may not be affecting learning. If an effect persists when the relevant variable is no longer present in the situation, then the effect is assumed to have been on learning. If, on the other hand, the effect disappears when the relevant variable is no longer present, the effect is assumed to have been on performance.

The task in all conditions of the experiment was to adjust the pitch of a variable tone to match that of a standard tone when 5 seconds of silence intervened between the two tones. There was a training session in which the relevant variables were introduced and a test session in which these variables were altered or removed. During the training session three levels of intensity (25, 50 and 75 decibels) were used with both the standard and variable tone. There were three feedback conditions; delayed auditory feedback, a control condition in which there was a 10 second interval of silence between the end of the allotted adjustment period and the beginning of another trial; visual feedback, in which the experimenter reported errors to the subject by pointing to a visual scale representing possible frequency deviations from the standard; and auditory feedback, in which the standard was presented immediately following the period allotted for adjustment. In the test condition the standard and variable were presented at 50 decibels with delayed feedback.

The following hypotheses were advanced: First, training with a 50 decibel standard will produce more accurate judgments in training and test conditions than training with a 25 or 75 decibel standard. Second, there will be an inverse relationship between intensity levels of the variable tone and accuracy of judgment in training and test conditions. Third, the order of effectiveness of feedback in training and test conditions will be

delayed feedback, visual feedback, and auditory feedback.

It was assumed that the effects mentioned in these hypotheses would not operate to the same extent for all subjects. In a task like pitch identification in which learning is presumed to occur and in which individual differences in performance exist, subjects capable of performing at an optimum level before training can change little as a result of practice. On the other hand, subjects who initially show little ability may improve greatly. Factors facilitating pitch identification, then, should reduce the variability of the groups to which they are applied.

The superiority of the 50 decibel standard was suggested on the basis of the notion that the loudness of a tone determines its effect on accuracy of judgment. Two points concerning intensity are important in connection with this assumption. First, increases in intensity magnify the defining characteristics of frequency. For example, an increase in the amplitude of a sine wave makes the distances between peaks and troughs in the wave larger. Since this magnification has its analogue within the organism in the form of increased neural firing with increased stimulus intensity, it was assumed that increased loudness would provide increased definition of pitch and in so doing would facilitate judgments in the training condition. Second, because intensity is an ever present characteristic of tone, the perception of pitch necessarily involves the perception of loudness. It was felt that high intensity would make loudness the dominant characteristic of tonal perception and thus would interfere with accurate judgments of pitch. These considerations suggest a curvilinear relationship between intensity and judgments of pitch.

It was assumed that the facilitating effects of the 50 decibel standard would continue to operate during the test session. If the 50 decibel group,

as predicted, were to make more accurate responses than other groups during the training session, they would have practiced correct responses more often than the other groups.

The inverse relationship between variable tone intensity and accuracy of judgment was assumed on the basis of the notion that the degree of interference of the variable tone on judgments of the standard would be a function of the intensity of the variable tone. The variable tone was expected regardless of intensity to exert an interfering affect on the standard. Such interference is simply an example of the well documented constant error associated with the method of adjustment (Guilford, 1954). The degree of the effect was assumed to be a function of the intensity of the variable tone. It was felt that the effect would carry over into test session performance in that subjects trained under highly interfering conditions would have less practice making correct responses than subjects trained under other conditions.

The rationale for the feedback hypothesis was as follows: The delayed feedback condition was regarded as a control condition. The information provided by the variable tone was expected to be almost totally dissipated by the end of the 10 second period of silence between the end of the adjustment period and the onset of the next trial. Accordingly, it was felt that both visual and auditory feedback would be more effective in decreasing errors in training and test conditions than delayed feedback.

The hypothesized superiority of the auditory feedback condition was based on the notion that there would be a loss of information if the visual channel were used to describe a relationship between a stimulus and response primarily involving the auditory channel. The visual and auditory feedback conditions both define quantitative dimensions providing a basis for

classifying judgments. The scale used in the visual feedback condition described a dimension representing possible deviations from the standard. The immediate comparison of the standard and variable tone afforded by the auditory feedback condition also provided a continuum of deviations from the standard. However, classifications occurring on the auditory dimension provided more readily usable information than those occurring on the visual dimension. It was assumed that in order for visual feedback to be effective, it would have to be translated into the auditory dimension. That is, values on the visual dimension would have to be made to correspond to those on the auditory dimension, and the possibility of information loss in the translation process seemed likely. Thus, it was assumed that judgments of subjects trained under auditory feedback would be superior to those of subjects trained under visual feedback.

Method.

One hundred eight subjects taken from the educational psychology subject pool at the University of Kansas were each assigned at random to one of the twenty-seven conditions described by the possible combinations of feedback and intensity used in the study.

The sound system used for the experiment consisted of two Houston Instrument Type J1 oscillators connected to an external switch box capable of channeling the sound from either oscillator into a set of Permoflux PDT8 earphones inside a sound-proof room. The frequency response of these earphones was $\pm .5$ decibels from 500 to 1700 cps. A Bruel and Kjaer sound level meter Type 2203 and artificial ear Type 4152 with condenser microphone Type 4131 were used to measure intensity. A frequency counter was used to measure frequency. The duration and sequence of tone presentation were automatically

controlled by interval timers. The oscillator that was adjusted by the subject was modified by covering the dial to prevent visual cues in repeated adjustments and was restricted in range to adjustments between 500 and 1700 cps. Prior to the beginning of each trial, the subject was instructed to set the variable tone to the appropriate extreme of the range. On trials one and two for all conditions the setting was 1700 cps, for trials three and four it was 500 cps. This pattern of alternation was continued for all trials. In all conditions there were 16 training trials and 12 test trials.

In the delayed auditory feedback condition, the standard was presented for 5 seconds and followed by 5 seconds of silence. Then the variable tone came on for 15 seconds during which time the subject made his judgment. There was a 10 second interval between the end of the judgment period and the onset of the next trail.

The visual feedback condition was the same as the delayed feedback condition with the exception that immediately following the adjustment period the subject was given visual feedback. The experimenter pointed to a visual scale on which the subject's judgments could be represented. The scale was divided into 22 $\frac{1}{4}$ -inch steps representing 22 equal intervals (i.e., semitones) from 500 to 1700 cycles per second. Each semitone could be subdivided into thirds by the experimenter. Thus, the error in reporting to the subject in a given instance could be no more than $\pm$ one sixth of a semitone.

The immediate auditory feedback condition was identical to the delayed feedback condition with the exception that the onset of a new trial followed the judgment period immediately.

The test condition was identical to the delayed feedback condition.

Results

The subjects' judgments were expressed in absolute deviations from the 932 cps standard. Because frequency does not describe pitch scale with equal

intervals, judgments were converted to logarithms. A subject's score was the mean log deviation of his responses. Means and variances of the mean log deviations of subjects' responses for each of the nine experimental conditions are presented in Table 5 for both training and test sessions. For convenience in interpretation these values are also expressed in semitones.

Table 5

Means and Variances of Subjects' Log Deviations in Training and Test Performances for the 9 Experimental Conditions Expressed in Logs and Semitones

Training Condition					Test Condition			
	Means		Variances		Means		Variances	
	Logs	Semitones	Logs	Semitones	Logs	Semitones	Logs	Semitones
S ₁	.05602	2.25	.00217	.10	.02748	1.10	.00195	.08
S ₂	.03306	1.31	.00080	.04	.02266	.92	.00160	.06
S ₃	.07206	2.88	.00339	.13	.05710	2.29	.00687	.29
V ₁	.04610	1.84	.00155	.08	.02400	.96	.00152	.06
V ₂	.06276	2.52	.00395	.17	.04558	1.83	.00365	.15
V ₃	.05222	2.10	.00164	.08	.03520	1.40	.00151	.06
F ₁	.06835	2.72	.00322	.13	.05182	2.08	.00336	.14
F ₂	.03958	1.58	.00231	.10	.02682	1.08	.00209	.10
F ₃	.05315	2.12	.00144	.06	.02861	1.14	.00102	.04

S = Standard

V = Variable

F = Feedback

Subscripts 1, 2, 3 refer to 25, 50, and 75 decibel conditions, or in the case of feedback to delayed, visual, and auditory feedback conditions.

As mentioned above, it was assumed that treatment effects would not operate equally for all subjects and that treatments facilitating judgment would reduce the variability of the groups to which they were applied. Accordingly, F tests were used to evaluate differences in group variability among conditions.

To test the superiority of the 50 decibel standard for both training and test sessions, F ratios were computed between each of the three pairs of intensity conditions defined by training session variations in the intensity level of the standard. Results are given for training and test sessions in Table 6. The data for the training session support the hypothesized superiority of the 50 decibel condition. For the test session, the predicted difference between the 25 and 50 decibel training groups was not supported. However, the 75 decibel condition was, as predicted, inferior to the 50 decibel condition.

Table 6

F Ratios Between Conditions Involving Variations
in Intensity of the Standard Tone

Source	Variances	d.f.	Comparison		F	P
<u>Train</u>						
S ₂₅	.002173	35	S ₂₅	S ₅₀	2.7190	.005
S ₅₀	.000799	35	S ₇₅	S ₅₀	4.2403	.005
S ₇₅	.003388	35	S ₇₅	S ₂₅	1.606	---
<u>Test</u>						
S ₂₅	.001954	35	S ₂₅	S ₅₀	----	---
S ₅₀	.001603	35	S ₅₀	S ₇₅	3.5143	.005
S ₇₅	.006867	35	S ₂₅	S ₇₅	4.2838	.005

F ratios for both training and test sessions computed for the three pairs of conditions defined by training session variations in intensity levels of the variable tone are given in Table 7. The results of these tests do not support the hypothesized inverse relationship between intensity level of the variable tone and training and test session performance. As predicted, the 25 decibel condition was superior to the 50 decibel condition in both training and test sessions. However, the 75 decibel group, which was predicted to show the poorest performance of the three groups, was in fact significantly superior to the 50 decibel group in both training and test sessions.

Table 7
F Ratios Between Conditions Involving Variations
in Intensity of the Variable Tone

Source	Variances	d.f.	Comparison		F	P
<u>Train</u>						
V ₂₅	.001549	35	V ₂₅	V ₅₀	2.5523	.010
V ₅₀	.003951	35	V ₂₅	V ₇₅	---	---
V ₇₅	.001643	35	V ₅₀	V ₇₅	2.4045	.010
<u>Test</u>						
V ₂₅	.001520	35	V ₂₅	V ₅₀	2.404	.01
V ₅₀	.003654	35	V ₂₅	V ₇₅	---	--
V ₇₅	.001511	35	V ₅₀	V ₇₅	2.3520	.01

To test the hypothesized order of effectiveness for the feedback conditions, F ratios were computed between the variances of scores for each of the three possible pairs of feedback conditions in the training and test sessions. The results of these tests for both training and test sessions are given in Table 8. The hypothesized effectiveness of auditory feedback received support.

The auditory condition was superior to the delayed condition for both training and test sessions, and to the visual condition for the test session. However, it was not significantly different from the visual condition in the training session. The hypothesized effects of the visual condition were not supported by the data.

Table 8
F Ratios Between Conditions Involving
Variations in Feedback

Source	Variances	d.f.	Comparison	F	P
<u>Train</u>					
F ₁	.00322	35	F ₁ F ₂	1.393	---
F ₂	.00231	35	F ₁ F ₃	2.236	.025
F ₃	.00144	35	F ₂ F ₃	1.604	---
<u>Test</u>					
F ₁	.00336	35	F ₁ F ₂	1.556	---
F ₂	.00209	35	F ₁ F ₃	2.184	.025
F ₃	.00102	35	F ₂ F ₃	2.046	.025

F₁ = Delayed feedback.

F₂ = Visual feedback.

F₃ = Auditory feedback.

Discussion

The observed superiority of the 50 decibel standard during the training session gives support to the hypothesis that increased intensity level provides increased definition of pitch as well as the notion that high level intensity can become an overriding characteristic interfering with pitch judgment. Shower and Biddulph (1931) also observed a relationship between intensity level and pitch judgment. However, in their study the relationship

did not persist beyond an approximate level of 20 decibels. In this connection it should be noted that in the Shower and Biddulph study there was almost no delay between the presentation of the standard and the ensuing judgment. Thus there was little opportunity for the stimulus trace to decay. It is possible that when long delays exist between stimulus presentation and judgment permitting increased opportunity for trace decay, the relationship between intensity level and accuracy of pitch judgment will be maintained at higher intensity levels.

The lack of significance between the 25 decibel condition and the 50 decibel condition in the test session is apparently due to the fact that the 50 decibel group became more variable in their performance during the test session than they had been during training. It is not clear why this should occur.

The data do not support the hypothesized interference effects associated with intensity level variations of the variable tone. Rather the results describe a mirror image of the findings given for the standard tone. Whereas the 50 decibel standard produces superior performance, the 50 decibel variable produces inferior performance. One possible explanation for the results observed with respect to variations in the variable tone is that magnification of the defining characteristics of pitch of the variable tone may interfere with judgments of the standard.

Training and test session data support the hypothesized effectiveness of auditory feedback. Despite the fact that the assumed effectiveness of visual feedback was not supported, it could well be misleading to suggest that visual feedback is not effective. Performance of the visual feedback group was in the predicted direction. Furthermore, although the variability of the visual group was not smaller than that of the delayed feedback

condition, the mean for the visual group was significantly higher than that for the delayed feedback group in both training and test sessions ($p < .005$). Visual feedback appears to affect learning though not in the manner predicted. Further research is necessary to precisely describe the differences between the effects of visual and auditory feedback.

The findings with respect to feedback are of interest in connection with an earlier study by Campbell and Small (1963) in which feedback was found to have a detrimental effect on pitch discrimination. There is variation between their method and that of the present study which could account for differences in results.

One important difference between the Campbell and Small investigation and the current study is that they used only visual feedback. It was suggested above that in order for visual feedback to be effective, it must be translated into the auditory dimension defined by the sounds which the subject experienced in the testing situation. In the Campbell and Small study, if the subject happened to hear two tones which to him were not perceptibly different, visual information suggesting that one was higher than another could not be translated to the auditory dimension for subsequent use. The relevance of visual feedback could come about only during the course of a number of trials as the subject began to apprehend the auditory dimension. For example, in some cases the subject might be sure that the variable was higher than the standard. Feedback would confirm his judgment. In other cases he might have an opinion about which he was unsure. Feedback might be most effective in such instances. It could conceivably take several trials for the influence of feedback to be demonstrated. Furthermore, in the early trials, a great deal of irrelevant visual information would be communicated to the subject. This could explain why Campbell and Small found feedback to be detrimental to performance in the early phases of their study.

Conclusions and Implications

In Experiment I it was found that learning did not occur when the delay between the standard and variable tone was 10 seconds. However, learning did occur when there was no S-V delay. These findings support the view that tonal memory is not based on sensory experience alone; the opportunity to make a response is important in gaining access to the long term memory system. The findings with respect to the S-V delay are directly applicable to education. They suggest that acquisition of pitch identification skill will be facilitated if students are allowed to make overt identifying responses immediately following the cessation of the tone to be remembered.

The findings on S-V delay also have implications for future research. The fact that the identifying response has been shown to be an important factor in memory formation suggests the need to define the essential features of this type of response. Is it necessary for the subject to actually adjust the oscillator dial to improve his judgments, or would it be sufficient for improvement if he were to hear the variable tone being adjusted to approximate the standard? If the latter proved to be the case, an identifying response might be thought of as a comparison of a tone with an approximation to the tone. However, perhaps it is necessary for the subject to adjust the dial or at least control the frequency of the variable tone in some way. If this is the case, the identifying response may be more closely associated with imitation than comparison. A third possibility is that both imitation and comparison are involved. The validity of these as well as other interpretations of the nature of the identifying response must be determined by future research.

The superiority of the 50 decibel standard and inferiority of the 50 decibel variable observed in Experiment III indicate that variations in

intensity affect tonal memory. These findings imply that a standard tone of moderate intensity should be used in training students to identify pitches and that the variable tone should be of either low or high intensity.

The findings in Experiment III indicate that auditory feedback is superior to visual feedback and delayed feedback in facilitating pitch identification. In training students to identify pitches, it is advantageous to provide immediate auditory feedback. The feedback findings suggest a number of issues which might be topics for future research. The first of these involves verbal feedback, one of the most frequent types of feedback used in music education and other areas of education. One would assume that verbal feedback would be no more useful in improving pitch identification skill than visual feedback. Although verbal feedback does make use of the auditory channel, the type of information provided by verbal feedback is different in its characteristics than that provided by auditory feedback as defined in Experiment III. One might assume that in order to be effective, verbal feedback like visual feedback would have to be translated into the auditory dimension defined by the series of possible tones above and below the standard. An investigation of the relative effectiveness of verbal and auditory feedback would provide a useful addition to present knowledge.

Further research would also be of value with regard to the problem of discovering the conditions which determine the effectiveness of visual and auditory feedback. Of particular importance is the relationship between the relative effectiveness of visual and auditory feedback and the time when feedback is presented. In Experiment III, feedback was given immediately following the adjustment period. It might be more beneficial to provide feedback as the subject made his adjustment. Furthermore, if this were done, visual feedback might prove more effective than it was shown to be in

Experiment III. Consider the following three training conditions: visual feedback, in which the subject is permitted to watch the display panel of a frequency counter as he makes his adjustment; binaural auditory feedback, in which the S and V tones are presented to both ears and in which the subject makes his adjustment while the standard tone is still on; and monaural auditory feedback which would differ from the binaural condition in one respect only, the standard would be presented to one ear and the variable to the other. A test session like the one in Experiment III might reveal an advantage for the visual and monaural conditions. When information about the standard and information about the variable are presented simultaneously, it may be advantageous to use more than one channel to process the information.

Another area of research connected with the feedback findings would involve the investigation of the effects of combining a condition in which there was no S-V delay with conditions involving visual and auditory feedback. It is important to determine whether additional facilitation of accuracy in judgment would occur as a result of combining two treatments each of which is effective in its own right. Beyond the implications of findings pertaining to the central hypotheses advanced in the project, there are certain additional, in part incidental findings which have implications for future research. When effective treatments were not applied interindividual variability tended to be large. However, inspection of individual records revealed a rather high degree of intraindividual consistency. When treatments were effective, they did not influence all subjects equally. These findings suggest that there may be advantage to using subjects as their own controls in pitch judgment studies. This procedure would make it possible to examine the effects of a given treatment on individual subjects and in so doing provide greater precision in establishing the relationship between treatment effects and individual characteristics of subjects.

References

- BERGAN, J. R. A study of the relationships between pitch perception, imagery and regression in the service of the ego. J. for Res. in mus. Educ., 1965, 13.
- BERGAN, J. R. The relationships among pitch identification, imagery for musical sounds and musical memory. J. for Res. in mus. Educ., in press.
- BERGSTROM, J. H. Effect of changes in the time interval in successive associations. Psychol. Rev., 1919, 26, 335-353.
- BROADBENT, D. E. Perception and communication. London: Pergamon Press, 1958.
- CAMPBELL, RICHARD A. and SMALL, A.M., JR. Effect of practice and feedback on frequency distribution. J. acous. Soc. Amer., 1963, 35, 1511-1514.
- EDWARDS, ALLEN L. Experimental design in psychological research. (revised ed.) New York: Holt, Rinehart and Winston, 1964.
- GUILFORD, J. P. Psychometric methods. New York: McGraw-Hill Book Company, Inc., 1954.
- GUTHRIE, E. R. Association as a function of time interval. Psychol. Rev., 1933, 40, 355-368.
- HARRIS, J. D. Pitch discrimination. J. acous. Soc. Amer., 1952, 24, 750-755.
- KONIG, E. Effect of time on pitch discrimination thresholds under several psychophysical procedures, comparisons with intensity discrimination threshold. J. acous. Soc. Amer., 1957, 29.
- McGEOCH, J. A., & IRION, A. L. The psychology of human learning. (2nd ed.) New York: Longmans, Green, 1952.
- McREYNOLDS, PAUL, & ACKER, MARY. Serial learning under conditions of rapid presentation of stimuli. Amer. J. Psychol., 1959 (Dec.), 72, 589-592.
- PETERSON, LLOYD, & PETERSON, MARGARET. Short-term retention of individual verbal items. J. exp. Psychol., 1959, 58, 193-198.

- PILLSBURY, W. B., & SYLVESTER, A. Retroactive and proactive inhibition in immediate memory. J. exp. Psychol. 1940, 27, 532-545.
- POLLACK, IRWIN, & JOHNSON, LAWRENCE B. Reproduction and identification of elements of auditory displays. J. acous. Soc. Amer., 1959, 31.
- SHOWER, E. G., & BIDDULPH, R. Differential pitch sensitivity of the ear. J. acous. Soc. Amer., 1931, 3, 275-287.
- SOLOMON, PHILIP, et al. Sensory deprivation: A symposium held at Harvard Medical School. Cambridge, Massachusetts: Harvard University Press, 1961.
- STEVENS, S. S. Handbook of experimental psychology. New York: Wiley, 1951.
- WILCOXON, FRANK, & WILCOX, ROBERTA A. Some rapid approximate statistical procedures. (revised) Pearl River, New York: Lederle Laboratories, 1964.
- WINER, B. J. Statistical principles in experimental design. New York: McGraw-Hill Book Company, Inc., 1962.